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(71) Applicant: **Welltec A/S**
3450 Allerød (DK)

(72) Inventors:
- **ANDERSEN, Tomas Sune**
3450 Allerød (DK)
- **SOMMER, Rasmus**
3450 Allerød (DK)

(74) Representative: **Dragsted Partners A/S**
Rådhuspladsen 16
1550 Copenhagen V (DK)

(54) DOWNHOLE RADIAL FORCE TOOL ASSEMBLY

(57) The present invention relates to a radial force tool assembly for providing a radial force perpendicularly to an axial extension of the radial force tool assembly in a well for anchoring, centralising or rolling a downhole intervention tool in a well having a borehole, the radial force tool assembly having a centre axis, a front end and a rear end, and comprising a tool body comprising a cavity extending across the tool body, the cavity comprising a first cavity face facing opposite a second cavity face, a first actuator moving a first force-transmitting member in relation to the tool body along the axial extension, wherein the first force-transmitting member has a first end with a first inclined face and a second inclined face, the first and second inclined faces inclining in opposite directions, and a first rear arm member having a first end face abutting the first inclined face and a second end face, and a second rear arm member having a first end face abutting the second inclined face and a second end face, and wherein each of the first end faces has a curvature following an involute of a circle, so that when the first force-transmitting member moves towards the front, the first end face of the first rear arm member rolls on the first inclined face, projecting the first rear arm member radially outwards in a first radial direction, and the first end face of the second rear arm member rolls on the second inclined face, projecting the second rear arm member radially outwards in a second radial direction opposite the first direction while projecting the first and second rear arm members. The invention also relates to a downhole intervention tool comprising the radial force tool assembly.

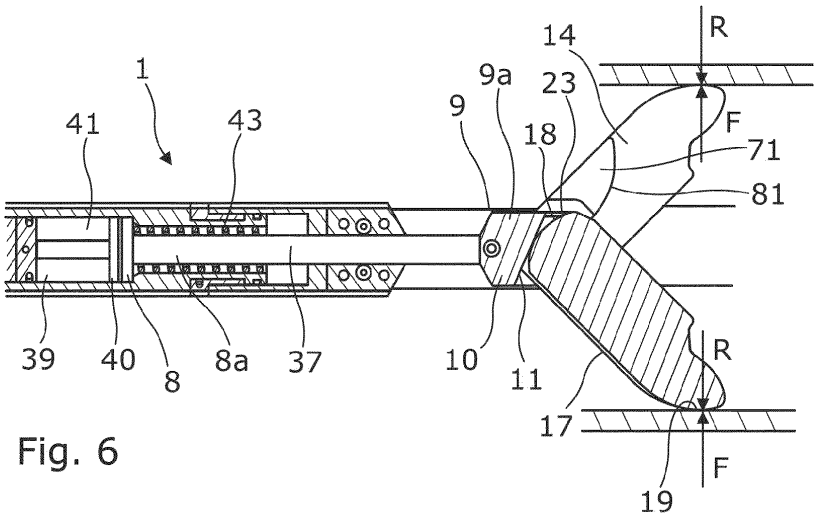

Fig. 6

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Description

[0001] The present invention relates to a radial force tool assembly for providing a radial force perpendicularly to an axial extension of the radial force tool assembly in a well for anchoring, centralising or rolling a downhole intervention tool in a well having a borehole, the radial force tool assembly having a centre axis, a front end and a rear end. The invention also relates to a downhole intervention tool comprising the radial force tool assembly.

[0002] Radial force generators are known in the hydrocarbon industry for anchoring a downhole tool in a well, e.g. for pulling or setting a plug, in order to transfer the axial force into a pulling or pushing force along the axial extension of the well tubular metal structure. Radial force generators may also be used for centralising a tool in the well for performing a certain operation needing centralising, such as logging or imaging.

[0003] Some wells have a narrow restriction, and the anchoring tool then needs to be set further downhole of the restriction so that the radial force generator has to have a sufficient radial extension, while still delivering sufficient force. The known radial force generators are not able to provide an extension of more than twice the outer diameter of the tool, which is not always enough. Therefore, attempts have been made to enhance the design to provide a longer radial extension, but when the generators are only projected in a small angle in relation to the axial extension of the tool, the radial force generator provides a very limited amount of force. A radial force generator is known from US 6,920,936, which has a very complex design where rollers on arms are arranged to support the projected arms when the arms are only slightly projected to overcome the problem of very limited force at small angles. However, such complicated design has many parts which may get stuck or worn out, and the known radial force generators still have a very limited radial extension.

[0004] It is an object of the present invention to wholly or partly overcome the above disadvantages and drawbacks of the prior art. More specifically, it is an object to provide an improved radial force tool assembly which can be used in a variety of well sizes and preferably have a longer radial extension than known tools.

[0005] Furthermore, it is an object to provide an improved radial force tool assembly which can enter a narrow restriction in the well and expand below the restriction in a section of the well which has an inner diameter of at least 3 times the inner diameter of the restriction, while still providing sufficient force to anchor an intervention tool.

[0006] The above objects, together with numerous other objects, advantages and features, which will become evident from the below description, are accomplished by a solution in accordance with the present invention by a radial force tool assembly for providing a radial force perpendicularly to an axial extension of the radial force tool assembly in a well for anchoring, centralising or rolling a downhole intervention tool in a well having a borehole, the radial force tool assembly having a centre axis, a front end and a rear end, and comprising:

- a tool body comprising a cavity extending across the tool body, the cavity comprising a first cavity face facing opposite a second cavity face,
- a first actuator moving a first force-transmitting member in relation to the tool body along the axial extension,
  wherein the first force-transmitting member has a first end with a first inclined face and a second inclined face, the first and second inclined faces inclining in opposite directions, and
- a first rear arm member having a first end face abutting the first inclined face and a second end face, and a second rear arm member having a first end face abutting the second inclined face and a second end face,

and wherein each of the first end faces has a curvature following an involute of a circle, so that when the first force-transmitting member moves towards the front, the first end face of the first rear arm member rolls on the first inclined face, projecting the first rear arm member radially outwards in a first radial direction, and the first end face of the second rear arm member rolls on the second inclined face, projecting the second rear arm member radially outwards in a second radial direction opposite the first direction while projecting the first and second rear arm members.

[0007] Furthermore, as the curvature may follow an involute of a circle, the first end face of the first rear arm member is enabled to roll and not slide on the first inclined face since the first rear arm member is projecting radially outwards in a first radial direction.

[0008] In prior art tools, the members are hingedly or "linkagely" connected, and this provides high friction causing wear in the connection. Furthermore, the force is translated almost entirely from the first force-transmitting member to the first and second rear members in an optimal manner.

[0009] Also, each of the first end faces may have a curvature following an involute of a circle, so that each first end face is shaped as the profile of half of a tooth of an involute gear.

[0010] Moreover, the first rear arm member or the first cavity face may comprise a projection engaging a guide in the other of the first rear arm member and the first cavity face, and the second rear arm member or the second cavity face may comprise a projection engaging a guide in the other of the second rear arm member and the second cavity face, wherein the projection of the first rear arm member going radially outwards in a first direction and the projection of the second rear arm member going radially outwards in a second direction opposite the first direction may be performed while the projections slide in the guides.

[0011] In addition, the radial force tool assembly may further comprise a first front arm member having a first end face and a second end face, and a second front arm member having a first end face and a second end face, the first front arm member or the first cavity face comprising a projection engaging a guide in the other of the first front arm member and the first cavity face, and the second front arm member or the second cavity face comprising a projection engaging a guide in the other of the second front arm member and the second cavity face.

[0012] Further, when projecting, the first rear arm member may extend in a first diagonal direction between the first radial direction and the axial extension, and at a first angle to the axial extension.

[0013] Also, when projecting, the second rear arm member may extend in a second diagonal direction between the second radial direction and the axial extension, and at a second angle to the axial extension.

[0014] Moreover, when projecting, the first front member may extend in a third diagonal direction between the first radial direction and the axial extension, and at a third angle to the axial extension.

[0015] Furthermore, when projecting, the second front member may extend in a fourth diagonal direction between the second radial direction and the axial extension, and at a fourth angle to the axial extension.

[0016] In addition, the first diagonal direction and the third diagonal direction may be parallel.

[0017] Further, the second diagonal direction and the fourth diagonal direction may be parallel.

[0018] Moreover, the first angle, the second angle, the third angle and the fourth angle may be of equal size.

[0019] Also, the cavity may extend along the axial extension.

[0020] Furthermore, the first rear arm member may be slidably arranged in the cavity and may have a first arm centre axis extending along the axial extension at a first distance to the centre axis of the radial force tool assembly.

[0021] Moreover, the second rear arm member may be slidably arranged in the cavity and may have a second arm centre axis extending along the axial extension at a second distance to the centre axis of the radial force tool assembly, and the first distance may be equal to the second distance.

[0022] In addition, the first front arm member may be slidably arranged in the cavity and may have the first arm centre axis.

[0023] Further, the second front arm member may be slidably arranged in the cavity and may have the second arm centre axis.

[0024] Also, the radial force tool assembly may further comprise a first contact element and a second contact element, the first contact element being connected with the second end faces of the first rear arm member and the first front arm member, and the second contact element being connected with the second end faces of the second rear arm member and the second front arm member.

[0025] Moreover, by having four arm members connected with two contact elements where the force is translated between an inclined face and a curvature following an involute of a circle, the translation of force may occur in a rolling motion like an involute gear.

[0026] In addition, the first contact element may be connected with the second end faces of the first rear arm member and the first front arm member by means of another projection engaging a guide, and the second contact element may be connected with the second end faces of the second rear arm member and the second front arm member by means of another projection engaging a guide.

[0027] Further, each of the first contact element and the second contact element may comprise a first face and a second face, the first face of the first contact element abutting the second end face of the first rear arm member, the second face of the first contact element abutting the second end face of the first front arm member, the first face of the second contact element abutting the second end face of the second rear arm member, and the second face of the second contact element abutting the second end face of the second front arm member.

[0028] Also, the first faces and the second faces may be inclined in relation to the axial extension.

[0029] Moreover, the first faces and the second faces may be curved.

[0030] In addition, each of the second end faces of the first and second rear arm members and the first and second front arm members may have a curvature following an involute of a circle, so that the second end face rolls on the first and second faces, and the first end faces of the first and second rear arm members roll on the inclined faces of the first force-transmitting member, projecting the arm members radially outwards while the projections slide in the guides.

[0031] By having four arm members connected with two contact elements where the force is translated between an inclined face and a curvature following an involute of a circle, the translation of force may occur in a rolling motion like an involute gear.

[0032] The first half of the involute tooth may be arranged as the first end face of the first rear arm member, the second half of the involute tooth may be arranged as the second end face of the first rear arm member, and the first inclined face of the first force-transmitting member and the first face of the first contact element may function as the engaging tooth, so that the first rear arm member is pressed in between the first face and the first inclined face. The other arm members may be arranged in a similar manner, and in this way the radial force at which the contact element presses towards the wall of the tubing or borehole is the same independently of the angle of the first rear arm member. This is very different from the known solutions using hinged connections, and where some also have a supporting roller structure.

[0033] Further, the radial force tool assembly may also

comprise a second actuator moving a second force-transmitting member in relation to the tool body along the axial extension, the second force-transmitting member having a first end with a first inclined face and a second inclined face, the first and second inclined faces inclining in opposite directions, wherein the first end face of the first front arm member abuts the first inclined face, and the first end face of the second front arm member abuts the second inclined face of the second force-transmitting member.

[0034] In that way, the arm members may be forced to move from both sides.

[0035] Also, the first contact element may have a first contact face facing radially outwards towards a wall of a tubing or the borehole, and the second contact element may have a first contact face facing radially outwards towards a wall of the borehole.

[0036] Moreover, the first contact faces of the first contact element and the second contact element may be equipped with projections such as spikes or similar projections for increasing the friction between the first contact faces and the wall.

[0037] In addition, the radial force tool assembly may be an anchoring tool assembly where the first contact element and the second contact element are equipped with projections such as spikes or similar projections for increasing the friction between the first faces and the wall.

[0038] Furthermore, the first contact faces of the first contact element and the second contact element may be equipped with rollers.

[0039] Also, the first contact element may be equipped with first engagement elements, each engaging a second engagement element of the first rear arm member and the first front arm member, respectively, and the second contact element may be equipped with first engagement elements, each engaging a second engagement element of the second rear arm member and the second front arm member, respectively.

[0040] Further, the cavity may be formed by a cut-out in the tool body and a lid plate.

[0041] Also, the first rear arm member may comprise a first wing profile having a wing curvature, the second rear arm member may comprise a first wing profile having a wing curvature, and the wing curvature of the first rear arm member may roll on the wing curvature of the second rear arm member when the arm members project from the tool body.

[0042] Moreover, the wing curvature may have a centre point positioned outside the radial force tool assembly.

[0043] In addition, the first rear arm member and the second rear arm member may slide in the cavity in a side-by-side manner so that the first wing profile and the second wing profile slide in relation to each other.

[0044] Further, the first front arm member may comprise a first wing profile having a wing curvature, the second front arm member may comprise a first wing profile having a wing curvature, and the wing curvature of the first front arm member may roll on the wing curvature of the second front arm member when the arm members project from the tool body.

[0045] Also, the actuator may be an electric actuator having an electric motor providing a linear movement of a shaft along the axial extension via a gear unit, or the actuator may be a hydraulic actuator that may comprise a piston moving in a chamber in the tool body along the axial extension.

[0046] Furthermore, a spring element in the chamber may be compressed as the piston moves to project the arm members.

[0047] Moreover, the arm members may have a retracted position in which the arm members are arranged in the cavity, and the arm members may have a projected position in which the arm members project from the tool body.

[0048] In addition, the force-transmitting member may have a projection sliding in a slot extending along the axial extension of the tool body.

[0049] Further, the tool body may have an outer diameter, and in the projected position of the arm members, the first face of the first contact element may have a distance to the first face of the second contact element, which distance may be at least 4 times the outer diameter.

[0050] Finally, the invention also relates to a downhole intervention tool comprising the radial force tool assembly and a stroking tool, and the downhole intervention tool may further comprise an electric motor powered by a wireline and driving a pump supplying hydraulic fluid to the stroking tool for providing an axial force on an element by means of a hydraulic cylinder.

[0051] The invention and its many advantages will be described in more detail below with reference to the accompanying schematic drawings, which for the purpose of illustration show some non-limiting embodiments and in which:

Fig. 1 shows a radial force tool assembly in a projected condition in a well tubular metal structure in a borehole for anchoring an intervention tool in a well before performing an operation in the well,

Fig. 2 shows another radial force tool assembly in a projected condition and used as a centraliser of an intervention tool,

Fig. 3 shows yet another radial force tool assembly in a projected condition and used as a roller,

Fig. 4 shows a partly cross-sectional view of another radial force tool assembly,

Fig. 5 shows another partly cross-sectional view of the radial force tool assembly of Fig. 4,

Fig. 6 shows yet another partly cross-sectional view of the radial force tool assembly of Fig. 4,

Fig. 7 shows a partly cross-sectional view of another radial force tool assembly,

Fig. 8 shows a partly cross-sectional view of part of another radial force tool assembly,

Fig. 9 shows a side of part of yet another radial force tool assembly where the arm members are retracted in the cavity, and

Fig. 10 shows a side of a downhole intervention tool having a radial force tool assembly and a stroking tool.

[0052] All the figures are highly schematic and not necessarily to scale, and they show only those parts which are necessary in order to elucidate the invention, other parts being omitted or merely suggested.

[0053] Fig. 1 shows a radial force tool assembly 1 providing a radial force F perpendicularly to an axial extension 2 of the radial force tool assembly in a well 3 for anchoring the radial force tool assembly 1 and preventing at least axial movement along the axial extension 2. The radial force tool assembly 1 thus also centralises the radial force tool assembly 1 in a well tubular metal structure 3a in a borehole 3b. The radial force tool assembly 1 has a centre axis L, a front end 4 and a rear end 5, and comprises a tool body 6 comprising a cavity 7 having a longitudinal extension along the axial extension 2 of the tool assembly and extending across the tool body 6. The cavity 7 comprises a first cavity face 7a facing opposite a second cavity face 7b, so that the cavity has two side faces being the first cavity face and the second cavity face. The radial force tool assembly 1 further comprises a first actuator 8, 8a moving a first force-transmitting member 9, 9a in relation to the tool body 6 along the axial extension 2. The first force-transmitting member 9, 9a has a first end 10 with a first inclined face 11 and a second inclined face 12, the first and second inclined faces inclining in opposite directions. The radial force tool assembly 1 further comprises a first rear arm member 14, and as shown in Fig. 4, the first rear arm member 14 has a first end face 15 abutting the first inclined face 11 and a second end face 16, and the radial force tool assembly 1 further comprises a second rear arm member 17 having a first end face 18 abutting the second inclined face 12 and a second end face 19. Each of the first end faces has a curvature 23 following an involute of a circle, so that when the first force-transmitting member 9, 9a moves from its initial position towards the front end 4, the first end face 15 of the first rear arm member 14 rolls on the first inclined face 11, projecting the first rear arm member radially outwards in a first radial direction D1, and the first end face 18 of the second rear arm member 17 rolls on the second inclined face 12, projecting the second rear arm member radially outwards in a second radial direction D2 opposite the first radial direction, while the first and second rear arm members move from a retracted position to a projected position as shown in Figs. 1-7 and 10.

[0054] The curvature 23 shown in Fig. 4 is following an involute of a circle, which enables the first end face 15 of the first rear arm member 14 to roll and not slide on the first inclined face 11 as the first rear arm member is projecting radially outwards in the first radial direction D1. In the same way, the first end face 15 of the second rear arm member 17 is enabled to roll and not slide on the second inclined face 12) while the first force-transmitting member 9, 9a moves from its initial position towards the front end 4. Each of the first end faces 15 has a curvature 23 following an involute of a circle, so that each first end face is shaped as the profile of half of a tooth of an involute gear.

[0055] In prior art tools, the members are hingedly or "linkagely" connected, and such connection provides high friction causing wear in the connection. Furthermore, in the present radial force tool assembly 1, the force is translated almost entirely from the first force-transmitting member 9, 9a to the first and second rear arm members 14, 17 in an optimal manner without losing a substantial amount of force.

[0056] In Fig. 4, the first rear arm member 14 or the first cavity face 7a comprises a projection 21, 21a engaging a guide 22, 22a in the other of the first rear arm member and the first cavity face, and the second rear arm member 17 or the second cavity face 7b comprises a projection 21, 21b engaging a guide 22, 22b in the other of the second rear arm member and the second cavity face. In the projection position as shown, the first rear arm member 14 projects radially outwards in the first direction D1, and the second rear arm member 17 projects radially outwards in the second direction D2 opposite the first direction, which radial projections are performed while the projections 21, 21a, 21b slide in the guides 22, 22a, 22b. By having projections and guides, the movement of the arm members 14, 17 is controlled as a pivot point/center P of the arm members is arranged outside the tool body 6 as shown in Fig. 7. The force from the actuator 8 is transferred from the first and second inclined faces 11, 12 to the curvature 23 of the first and second rear arm members 14, 17. This force is again transferred to the wall of the well tubular metal structure 3a or the borehole 3b via the second end faces 16, 19.

[0057] As shown in Fig. 6, the first rear arm member 14 comprises a first wing profile 71 having a wing curvature 81, and the second rear arm member 17 comprises a first wing profile 72 (shown in Fig. 5) having a wing curvature 82 (shown in Fig. 5), where the wing curvature 81 of the first rear arm member 14 rolls on the wing curvature 82 of the second rear arm member 17 when the arm members project from the tool body 6. In this way, the first and second rear arm members 14, 17 provide support for each other so that a resulting force R, i.e. a pushing force, from the wall is transferred from the first rear arm member 14 to the second rear arm member 17 and vice versa via the wing profiles 71, 72, which are a part of the arm

members. The first and second rear arm members 14, 17 are retracted via an engagement between the first force-transmitting member 9, 9a and each of the first and second rear arm members 14, 17, so that when the first force-transmitting member 9, 9a is retracted by the actuator 8, the first force-transmitting member 9, 9a engages the first and second rear arm members 14, 17. The wing profiles 71, 72 thus provide a rolling radius face along which the arm members 14, 17 are rolling and supporting each other without losing any substantial force. In this way, the first and second rear arm members 14, 17 are projected from the tool body 6 and provide a radial force F to the wall of the well tubular metal structure 3a where the force from the actuator 8 is almost directly transferred to the wall, and the force is transferred in an equal manner to both the first and second rear arm members 14, 17. As shown in Fig. 7, the wing curvatures 81, 82 shown in Fig. 5 have the centre point P positioned outside the radial force tool assembly 1.

[0058] The radial force tool assembly 1 further comprises a first front arm member 24 and a second front arm member 27 as shown in Fig. 1. As shown in Fig. 4, the first front arm member 24 has a first end face 25 and a second end face 26, and the second front arm member 27 has a first end face 28 and a second end face 29. The first front arm member 24 or the first cavity face 7a comprises a projection 21, 21ca engaging a guide 22, 22c in the other of the first front arm member and the first cavity face 7a, and the second front arm member 27 or the second cavity face 7, 7b comprises a projection 21, 21d engaging a guide 22, 22d in the other of the second front arm member 27 and the second cavity face 7b.

[0059] When projected as shown in Fig. 1, the first rear arm member 14 extends in a first diagonal direction DD1 between the first radial direction D1 and the axial extension 2, and at a first angle $\alpha 1$ to the axial extension, and the second rear arm member 17 extends in a second diagonal direction DD2 between the second radial direction D2 and the axial extension, and at a second angle $\alpha 2$ to the axial extension. The first front arm member 24 extends in a third diagonal direction DD3 between the first radial direction D1 and the axial extension 2, and at a third angle $\alpha 3$ to the axial extension, and the second front arm member 27 extends in a fourth diagonal direction DD4 between the second radial direction D2 and the axial extension, and at a fourth angle $\alpha 4$) to the axial extension. The first diagonal direction DD1 and the third diagonal direction DD3 are parallel, and the second diagonal direction DD2 and the fourth diagonal direction DD4 are parallel. The first angle $\alpha 1$, the second angle $\alpha 2$, the third angle $\alpha 3$ and the fourth angle $\alpha 4$ are of equal size.

[0060] In Fig. 9, the cavity 7 extends along the axial extension 2. The first rear arm member 14 is slidably arranged in the cavity 7 and has a first arm centre axis A1 extending along the axial extension 2 at a first distance D1 to the centre axis L of the radial force tool assembly 1. The second rear arm member 17 is slidably arranged in the cavity 7 and has a second arm centre axis A2 extending along the axial extension 2 at a second distance D2 to the centre axis L of the radial force tool assembly 1, the first distance being equal to the second distance. The first front arm member 24 is slidably arranged in the cavity 7 and has the first arm centre axis A1.

[0061] The second front arm member 27 is slidably arranged in the cavity 7 and has the second arm centre axis A2. The cavity 7 is formed by a cut-out 60 in the tool body 6 providing the second cavity face 7b and a lid plate 61 providing the first cavity face 7a. The first rear arm member 14 and the second rear arm member 17 slide in the cavity 7 in a side-by-side manner so that the first wing profile 71 and the second wing profile 72 slide in relation to each other.

[0062] The radial force tool assembly 1 further comprises a first contact element 30 and a second contact element 31 as shown in Fig. 1. The first contact element 30 is connected with the second end faces 16, 26 of the first rear arm member 14 and the first front arm member 24, and the second contact element 31 is connected with the second end faces 19, 29 of the second rear arm member 17 and the second front arm member 27. By having four arm members 14, 17, 24, 27 connected with two contact elements 30, 31, the force is translated between an inclined face and a curvature following an involute of a circle, and the translation and transferring of force occurs in a rolling motion like an involute gear.

[0063] In Fig. 2, the first contact element 30 is connected with the second end faces 16, 26 of the first rear arm member 14 and the first front arm member 24 by means of another projection 21, 21e engaging a guide 22, 22e, and the second contact element 31 is connected with the second end faces 19, 29 of the second rear arm member 17 and the second front arm member 27 by means of another projection 21, 21f engaging a guide 22, 22f.

[0064] In another embodiment as shown in Fig. 4, each of the first contact element 30 and the second contact element 31 comprises a first face 64 and a second face 65. The first face 64 of the first contact element 30 abuts the second end face 16 of the first rear arm member 14, and the second face 65 of the first contact element 30 abuts the second end face 26 of the first front arm member 24. Also, he first face 64 of the second contact element 31 abuts the second end face 19 of the second rear arm member 17, and the second face 65 of the second contact element 31 abuts the second end face 29 of the second front arm member 27. In Fig. 4, the first faces 64 and the second faces 65 are inclined in relation to the axial extension 2, but in another embodiment not shown, the first faces (64) and the second faces 65 may be curved. Each of the second end faces 16, 19, 26, 29 of the first and second rear arm members 14, 17 and the first and second front arm members 24, 27 has a curvature 23b following an involute of a circle, so that the second end faces rolls on the first and second faces, and the first end faces of the first and second rear arm members roll

on the inclined faces of the first force-transmitting member 9, 9a, projecting the arm members radially outwards while the projections slide in the guides.

[0065] By having four arm members 14, 17, 24, 27 connected with two contact elements 30, 31 where the force is translated between an inclined face 11, 12, 64, 65 and a curvature 23, 23b following an involute of a circle, the translation of force occurs in a rolling motion like an involute gear. The first half of the involute tooth is arranged as the first end face 15 of the first rear arm member 14, the second half of the involute tooth is arranged as the second end face 16 of the first rear arm member 14, and the first inclined face 11 of the first force-transmitting member 9, 9a and the first face 64 of the first contact element 30 function as the engaging tooth, so that the first rear arm member 14 is pressed in between the first face and the first inclined face. The other arm members 17, 24, 27 are arranged in a similar manner, and in this way the radial force at which the contact elements 30, 31 press towards the wall of the tubing or borehole 3b is the same independently of the angle of the arm members 14, 17, 24, 27. This is very different from the known solutions which use hinged connections, and where some also have a supporting roller structure.

[0066] The radial force tool assembly 1 further comprises a second actuator 8, 8b moving a second force-transmitting member 9, 9b in relation to the tool body 6 along the axial extension 2 in an opposite direction of the second force-transmitting member 9, 9b. The first and second actuators 8, 8a, 8b are linked so as to be moved by the same fluid or the same motor, and if moved by two motors, the motors are synchronised to move synchronically. The second force-transmitting member 9, 9b has a first end 32 with a first inclined face 33 and a second inclined face 34, and the first and second inclined faces 33, 34 are inclining in opposite directions. The first end face 25 of the first front arm member 24 abuts the first inclined face 33, and the first end face 28 of the second front arm member 27 abuts the second inclined face 34 of the second force-transmitting member 9, 9b. Thus, by having the first force-transmitting member and the second force-transmitting member moving towards each other, the arm members are forced to move from both sides. The inclined faces of the force-transmitting members transfer the force to the second end faces of the arm members and further to the inclined first and second faces of the contact elements via the first end faces of the arm members.

[0067] In Fig. 1, the first contact element 30 has a first contact face 45, 45a facing radially outwards towards a wall 44 of the tubing/well tubular metal structure 3a or the borehole 3b, and the second contact element 31 has a first contact face 45, 45b facing radially outwards towards the wall 44 of the borehole 3b. The first contact faces 45, 45a of the first contact element 30 and the second contact element 31 are equipped with projections 46 such as spikes or similar projections for increasing the friction between the first contact faces 45, 45a and the wall 44. The radial force tool assembly 1 is thus an anchoring tool assembly.

[0068] In Fig. 3, the radial force tool assembly 1 is used to roll a downhole intervention tool 50 in the well 3. Thus, the first contact faces 45, 45a, 45b of the first contact element 30 and the second contact element 31 are equipped with rollers 47 so that the downhole intervention tool is supported in a rolling manner while moving in the well.

[0069] To ensure that one of the first rear arm member 14 and the first front arm member 24 is not projected more than the other of the first rear arm member and the first front arm member, the first contact element 30 is equipped with first engagement elements 48, 48a, 48b, as shown in Fig. 5, where each first engagement element engages a second engagement element 49, 49a, 49b of the first rear arm member 14 and the first front arm member 24, respectively. Likewise, the second contact element 31 is equipped with first engagement elements 52, 52a, 52b, where each engages a second engagement element 53, 53a, 53b of the second rear arm member 17 and the second front arm member 27, respectively.

[0070] The first front arm member 24 comprises a first wing profile 73 having a wing curvature 83, the second front arm member 27 comprises a first wing profile 74 having a wing curvature 84, and the wing curvature 83 of the first front arm member 24 rolls on the wing curvature 84 of the second front arm member 27 when the arm members project from the tool body 6. In this way, the first and second front arm members 24, 27 provide support for each other so that a resulting force R, i.e. a pushing force, from the wall is transferred from the first front arm member to the second front arm member and vice versa via the wing profiles 73, 74, which are a part of the arm members. The first and second rear arm members 14, 17 and the first and second front arm members 24, 27 are retracted via an engagement between the first and second force-transmitting members 9, 9a, 9b and each of the first and second front arm members 24 ,27 so that when the first and second force-transmitting member 9, 9a, 9b is retracted by the actuator 8, 8a, 8b, the first and second force-transmitting member 9, 9a, 9b engages the arm members 14, 17, 24, 27. The wing profiles 71, 72, 73, 74 thus provide a rolling radius face along which the arm members 14, 17, 24, 27 are rolling and supporting each other without losing any substantial force. Thus, in the same way as the rear arm members 14, 17, the first and second front arm members 24, 27 are projected from the tool body 6 and provide a radial force F to the wall of the well tubular metal structure 3a, where the force from the second actuator 8, 8b is almost directly transferred to the wall, and the force is transferred in an equal manner to both the first and second front arm members. As shown in Fig. 7, the wing curvatures 83, 84 have a centre point P positioned outside the radial force tool assembly 1, and in the same way the wing curvatures 83, 84 of the first and second front arm members 24, 27 have a centre point P

positioned outside the radial force tool assembly 1. Returning to Fig. 9, the first front arm member 24 and the second front arm member 27 slide in the cavity 7 in a side-by-side manner so that the first wing profile 73 and the second wing profile 74 slide in relation to each other.

[0071] In Fig. 7, the actuator 8 is an electric actuator 35 having an electric motor 36 providing a linear movement of a shaft 37 along the axial extension 2 via a gear unit 38, and in Fig. 6 the actuator 8 is a hydraulic actuator 39 that comprises a piston 40 moving in a chamber 41 in the tool body 6 along the axial extension 2. A spring element 43 in the chamber 41 is compressed as the piston 40 moves to project the arm members 14, 17, 24, 27. The first force-transmitting member 9, 9a and/or the second force-transmitting member 9, 9b is connected to the shaft 37, and fluid may at least partly flow from the pump to the chamber 41 and to the hydraulic actuator 39 via fluid channels. Part of the fluid channels may be arranged in the tool body 6 with an outlet opposite the chamber 41. The radial force tool assembly 1 has a first fluid channel for pumping fluid into the chamber 41 on a first side of the piston 40 for moving the piston and thus the force-transmitting member 9, 9a, 9b to project the arm members, and the radial force tool assembly has a second fluid channel for returning the fluid in the chamber to the other second side of the piston.

[0072] As shown in Fig. 9, the arm members 14, 17, 24, 27 have a retracted position in which the arm members are arranged in the cavity 7, and as shown in Figs. 1-7 and 10, the arm members have a projected position in which the arm members project from the tool body 6.

[0073] The force-transmitting member 9 has a projection 62 sliding in a slot 63 extending along the axial extension 2 of the tool body 6 as shown in Fig. 8. The projection 21 is shown engaging a guide 22, and the guide and the projection have a curvature following an involute of a circle with the centre/pivot point P positioned outside the radial force tool assembly 1.

[0074] As shown in Fig. 10, the tool body 6 has an outer diameter OD, and in the projected position of the arm members 14, 17, 24, 27, the first contact face 64 of the first contact element 30 has a distance D to the first contact face 64 of the second contact element 31, and this distance is at least 4 times the outer diameter OD. The radial force tool assembly 1 is thus able to project from the outer diameter OD to the distance D, which is at least 3 times, preferably at least 4 times, the outer diameter of the tool body 6.

[0075] Fig. 10 shows a downhole intervention tool 50 comprising the radial force tool assembly 1 and a stroking tool 94, and the downhole intervention tool further comprises an electric motor 92 powered by a wireline 91 and driving a pump 93 supplying hydraulic fluid to the stroking tool for providing an axial force on an element 95 by means of a hydraulic cylinder 96.

[0076] A stroking tool is a tool providing an axial force. The stroking tool comprises an electric motor for driving a pump. The pump pumps fluid into a piston housing to move a piston acting therein. The piston is arranged on the stroker shaft. The pump may pump fluid out of the piston housing on one side and simultaneously suck fluid in on the other side of the piston.

[0077] By fluid or well fluid is meant any kind of fluid that may be present in oil or gas wells downhole, such as natural gas, oil, oil mud, crude oil, water, etc. By gas is meant any kind of gas composition present in a well, completion or open hole, and by oil is meant any kind of oil composition, such as crude oil, an oil-containing fluid, etc. Gas, oil and water fluids may thus all comprise other elements or substances than gas, oil and/or water, respectively.

[0078] By tubing, casing or well tubular metal structure is meant any kind of pipe, tubing, tubular, liner, string, etc., used downhole in relation to oil or natural gas production.

[0079] In the event that the tool is not submergible all the way into the casing, a downhole tractor can be used to push the tool all the way into position in the well. The downhole tractor may have projectable arms having wheels, wherein the wheels contact the inner surface of the casing for propelling the tractor and the tool forward in the casing. A downhole tractor is any kind of driving tool capable of pushing or pulling tools in a well downhole, such as a Well Tractor®.

[0080] Although the invention has been described above in connection with preferred embodiments of the invention, it will be evident to a person skilled in the art that several modifications are conceivable without departing from the invention as defined by the following claims.

Claims

1. A radial force tool assembly (1) for providing a radial force (F) perpendicularly to an axial extension (2) of the radial force tool assembly in a well for anchoring, centralising or rolling a downhole intervention tool (50) in a well (3) having a borehole (3b), the radial force tool assembly having a centre axis (L), a front end (4) and a rear end (5), and comprising:

    - a tool body (6) comprising a cavity (7) extending across the tool body, the cavity comprising a first cavity face (7a) facing opposite a second cavity face (7b),
    - a first actuator (8, 8a) moving a first force-transmitting member (9, 9a) in relation to the tool body along the axial extension,
    wherein the first force-transmitting member has a first end (10) with a first inclined face (11) and a second inclined face (12), the first and second inclined faces inclining in opposite directions, and
    - a first rear arm member (14) having a first end face (15) abutting the first inclined face and a second end face (16), and a second rear arm

member (17) having a first end face (18) abutting the second inclined face and a second end face (19), and wherein each of the first end faces has a curvature (23) following an involute of a circle, so that when the first force-transmitting member moves towards the front, the first end face (15) of the first rear arm member rolls on the first inclined face (11), projecting the first rear arm member radially outwards in a first radial direction (D1), and the first end face (18) of the second rear arm member rolls on the second inclined face (12), projecting the second rear arm member radially outwards in a second radial direction (D2) opposite the first direction while projecting the first and second rear arm members.

2. A radial force tool assembly according to claim 1, wherein the first rear arm member or the first cavity face comprises a projection (21, 21a) engaging a guide (22, 22a) in the other of the first rear arm member and the first cavity face, and the second rear arm member or the second cavity face comprises a projection (21, 21b) engaging a guide (22, 22b) in the other of the second rear arm member and the second cavity face, wherein the projection of the first rear arm member radially outwards in a first direction (D1) and the projection of the second rear arm member radially outwards in a second direction (D2) opposite the first direction are performed while the projections slide in the guides.

3. A radial force tool assembly according to claim 2, further comprising a first front arm member (24) having a first end face (25) and a second end face (26), and a second front arm member (27) having a first end face (28) and a second end face (29), the first front arm member or the first cavity face comprising a projection (21, 21b) engaging a guide (22, 22b) in the other of the first front arm member and the first cavity face, and the second front arm member or the second cavity face comprising a projection (21, 21b) engaging a guide (22, 22b) in the other of the second front arm member and the second cavity face.

4. A radial force tool assembly according to claim 2 or 3, wherein the radial force tool assembly further comprises a first contact element (30) and a second contact element (31), the first contact element being connected with the second end faces of the first rear arm member and the first front arm member, and the second contact element being connected with the second end faces of the second rear arm member and the second front arm member.

5. A radial force tool assembly according to claim 4, wherein the first contact element is connected with the second end faces of the first rear arm member and the first front arm member by means of another projection (21, 21c) engaging a guide (22, 22c), and the second contact element is connected with the second end faces of the second rear arm member and the second front arm member by means of another projection (21, 21d) engaging a guide (22, 22d).

6. A radial force tool assembly according to claim , wherein each of the first contact element (30) and the second contact element (31) comprises a first face (64) and a second face (65), the first face of the first contact element abutting the second end face of the first rear arm member, the second face of the first contact element abutting the second end face of the first front arm member, the first face of the second contact element abutting the second end face of the second rear arm member, and the second face of the second contact element abutting the second end face of the second front arm member.

7. A radial force tool assembly according to claim 6, wherein each of the second end faces of the first and second rear arm members and the first and second front arm members has a curvature (23b) following an involute of a circle, so that the second end face rolls on the first and second faces, and the first end faces of the first and second rear arm members roll on the inclined faces of the first force-transmitting member, projecting the arm members radially outwards while the projections slide in the guides.

8. A radial force tool assembly according to any of claims 3-7, further comprising a second actuator (8, 8b) moving a second force-transmitting member (9, 9b) in relation to the tool body along the axial extension, the second force-transmitting member having a first end (32) with a first inclined face (33) and a second inclined face (34), the first and second inclined faces inclining in opposite directions, wherein the first end face (25) of the first front arm member abuts the first inclined face (33), and the first end face (28) of the second front arm member abuts the second inclined face (34) of the second force-transmitting member.

9. A radial force tool assembly according to any of claims 3-8, wherein the first contact element (30) has a first contact face (45, 45a) facing radially outwards towards a wall (44) of a tubing (3a) or the borehole (3b), and the second contact element (31) has a first contact face (45, 45b) facing radially outwards towards the wall (44) of the borehole (3b).

10. A radial force tool assembly according to claim 9, wherein the first contact faces of the first contact element and the second contact element are

equipped with projections (46) such as spikes or similar projections for increasing the friction between the first contact faces and the wall.

11. A radial force tool assembly according to claim 9, wherein the first contact faces of the first contact element and the second contact element are equipped with rollers (47).

12. A radial force tool assembly according to any of the preceding claims, wherein the first rear arm member (14) comprises a first wing profile (71) having a wing curvature (81), the second rear arm member (17) comprises a first wing profile (72) having a wing curvature (82), and the wing curvature (81) of the first rear arm member rolls on the wing curvature (82) of the second rear arm member when the arm members project from the tool body.

13. A radial force tool assembly according to any of the preceding claims, wherein the actuator is an electric actuator (35) having an electric motor (36) providing a linear movement of a shaft (37) along the axial extension via a gear unit (38), or the actuator is a hydraulic actuator (39) that comprises a piston (40) moving in a chamber (41) in the tool body along the axial extension.

14. A radial force tool assembly according to any of the preceding claims, wherein the tool body has an outer diameter (OD), and in the projected position of the arm members, the first contact face of the first contact element has a distance (D) to the first contact face of the second contact element, which distance is at least 4 times the outer diameter.

15. A downhole intervention tool (50) comprising the radial force tool assembly according to any of the preceding claims and a stroking tool (94), and the downhole intervention tool further comprises an electric motor (92) powered by a wireline (91) and driving a pump (93) supplying hydraulic fluid to the stroking tool for providing an axial force on an element (95) by means of a hydraulic cylinder (96).

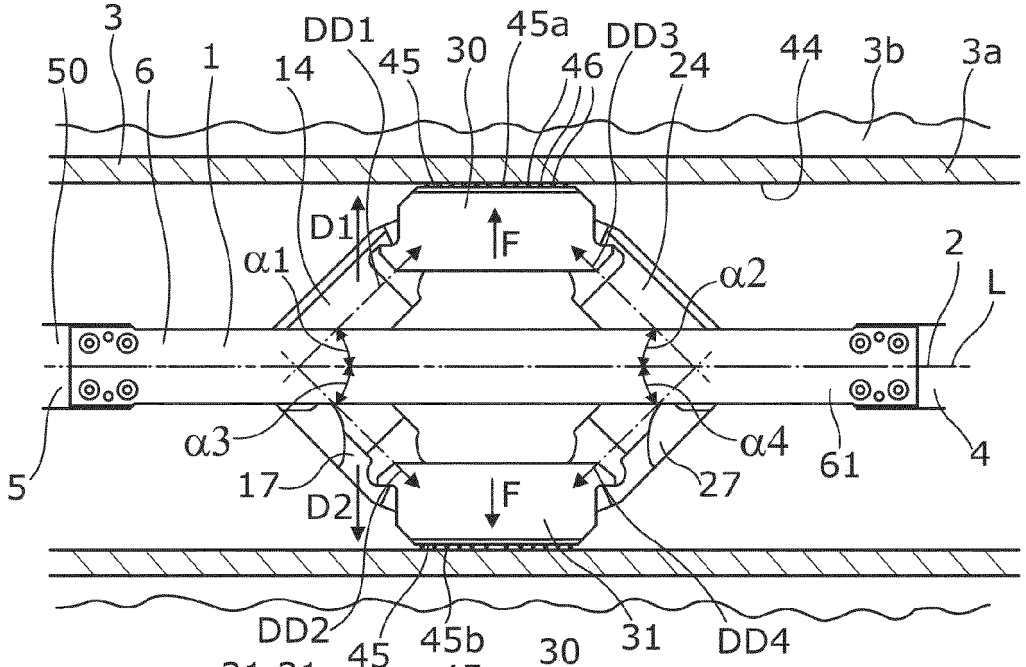

Fig. 1

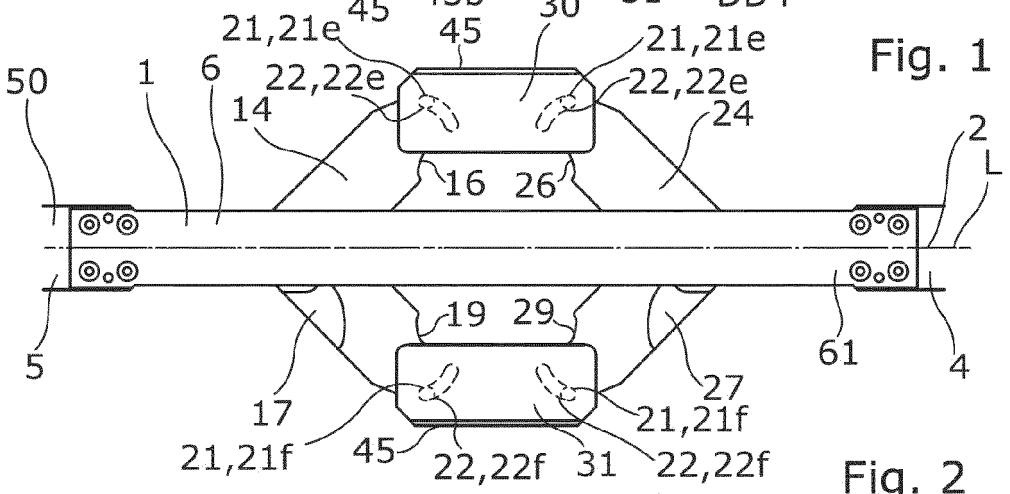

Fig. 2

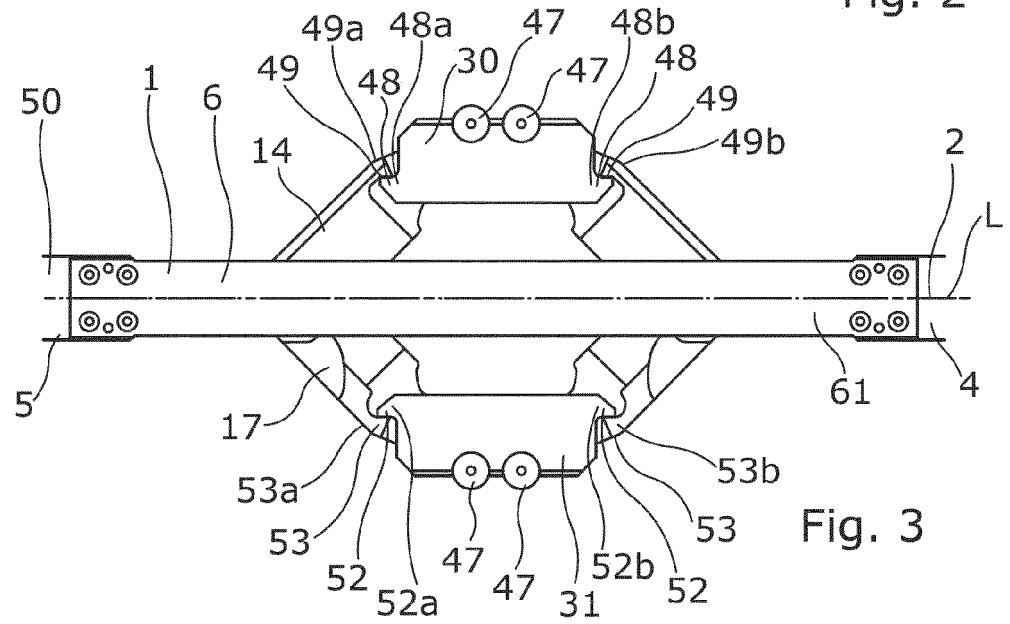

Fig. 3

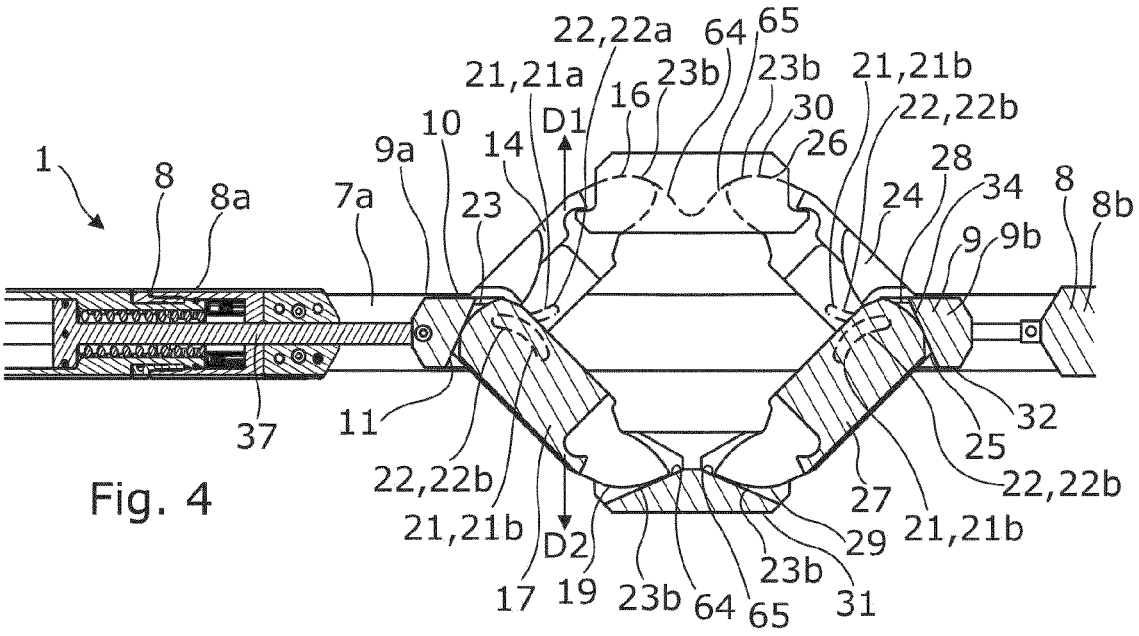

Fig. 4

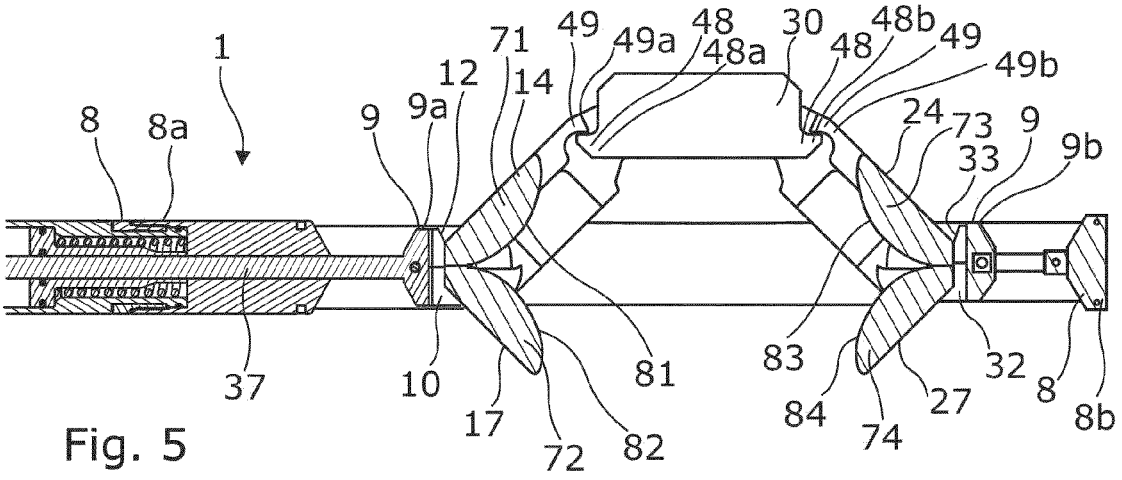

Fig. 5

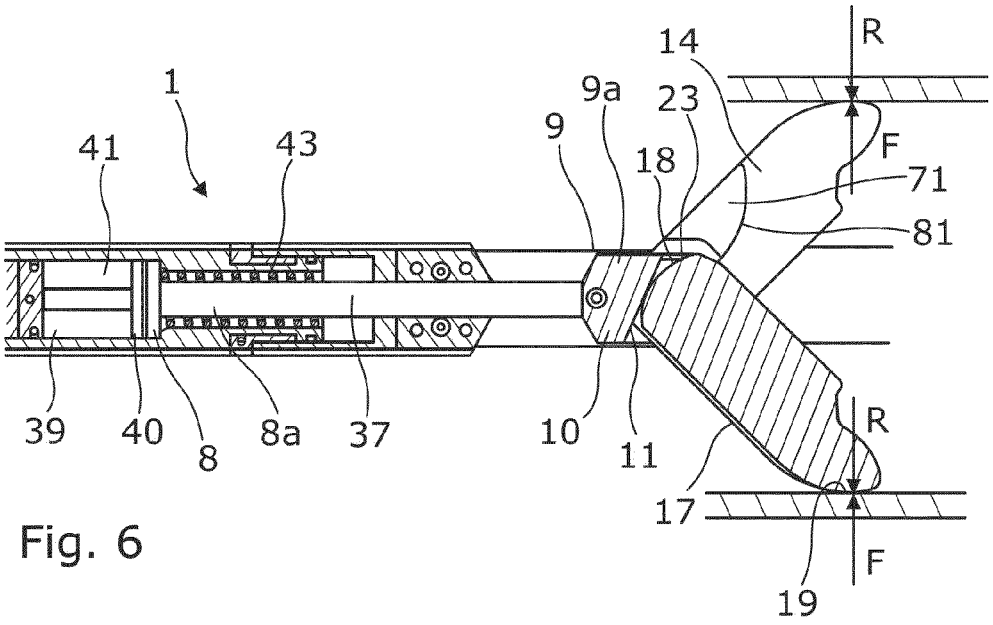

Fig. 6

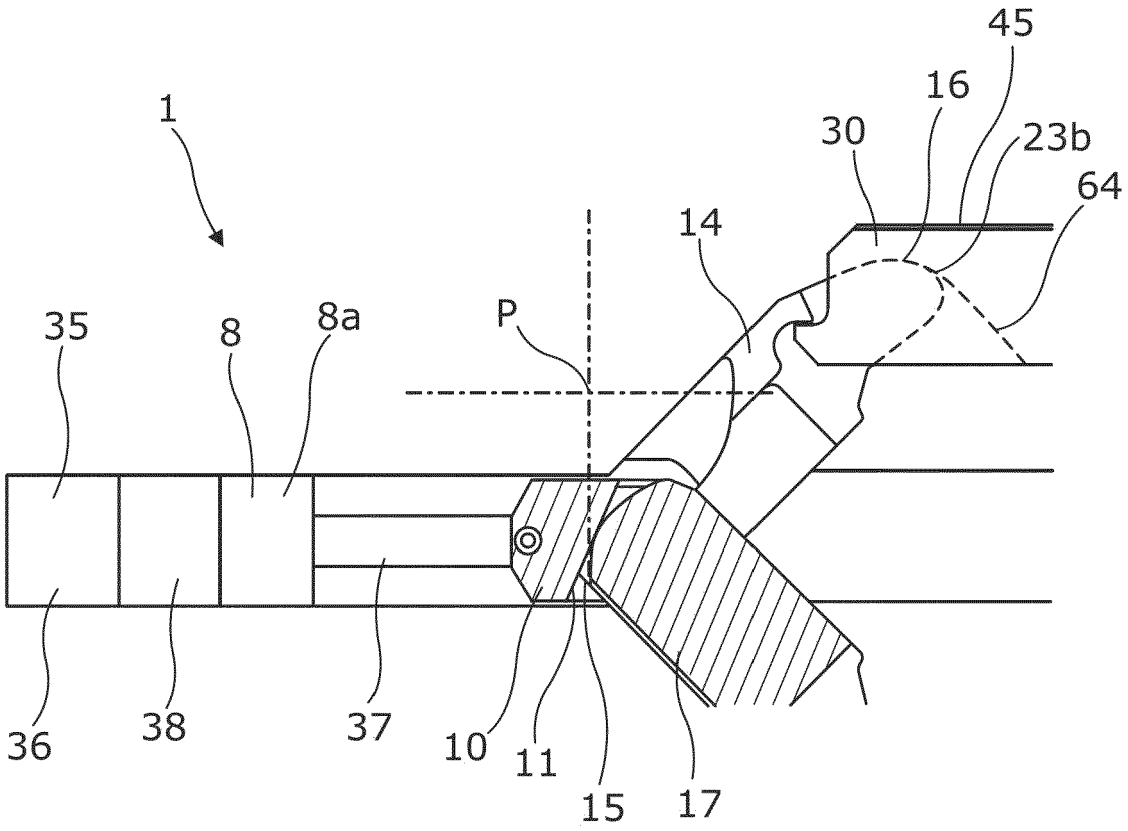

Fig. 7

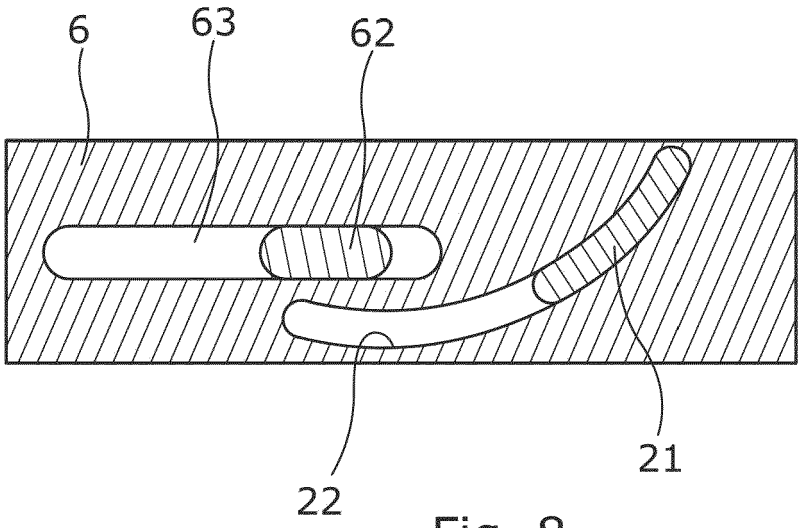

Fig. 8

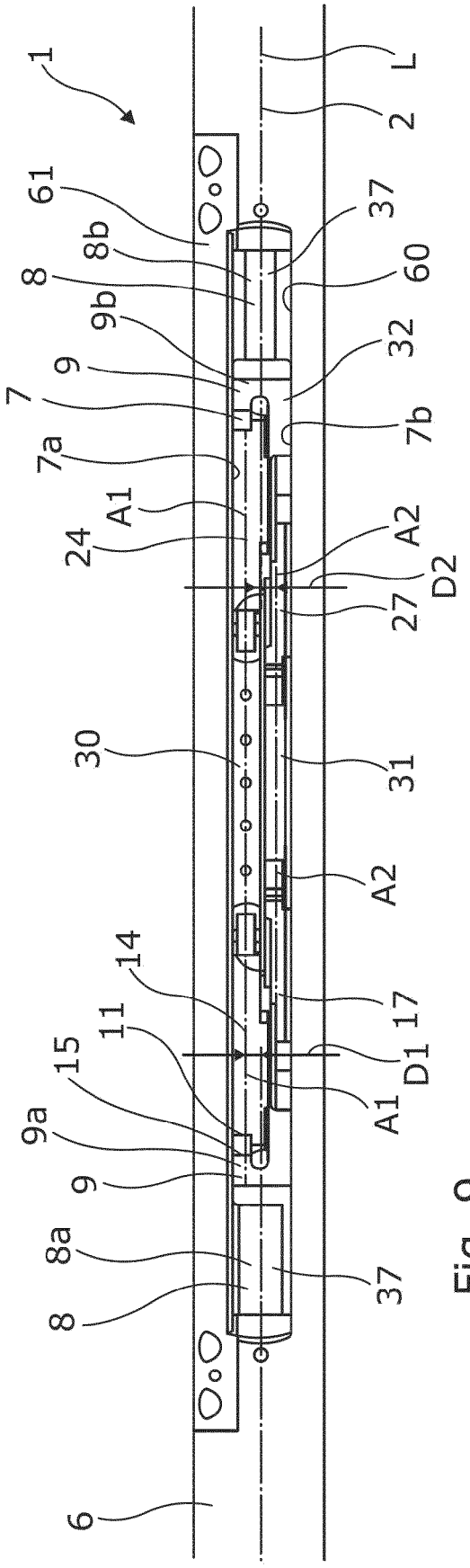
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Fig. 9

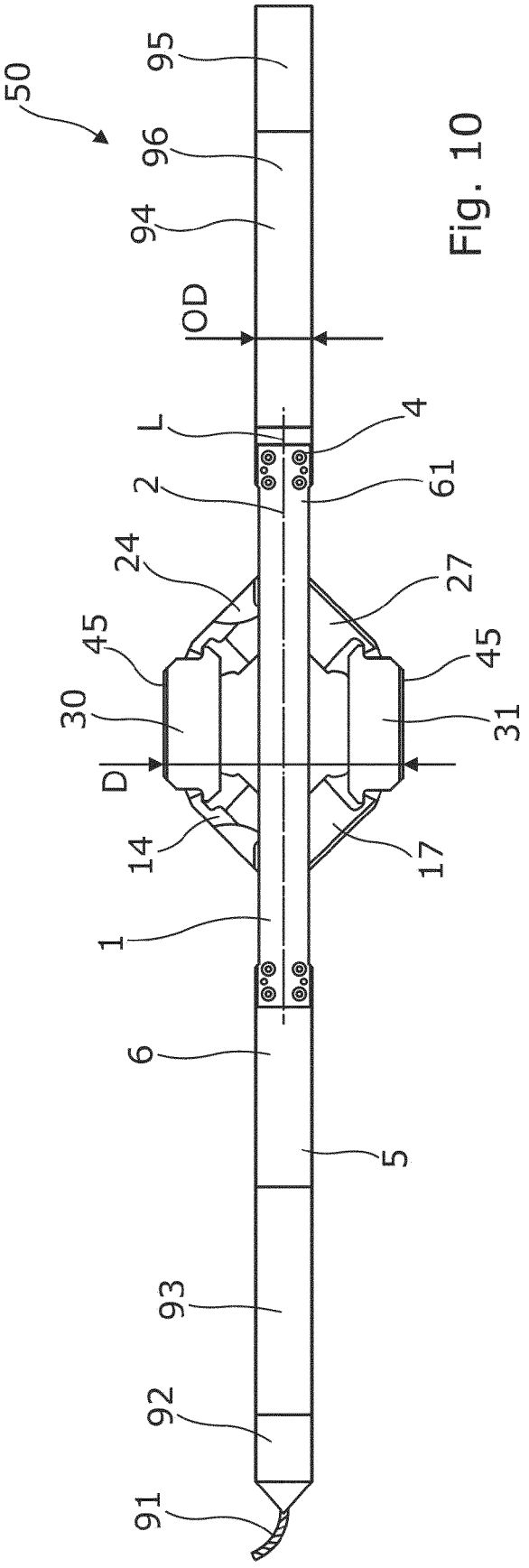
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Fig. 10

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EUROPEAN SEARCH REPORT

Application Number
EP 23 17 4932

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	11 October 2023	Georgescu, Mihnea

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